

Key Issues and Unmet Needs: Microbial Pathogens  
Great Lakes Nonpoint Source Pollution from Land Use Workshop

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This talk will present an overview of the types of microbial pathogens that might be associated with nonpoint sources of pollution. This will include a brief description of sources, the types of health effects and data sources including surveillance. Finally a discussion on data needs and gaps.

**Sources, Types and Pathways:**

**Sources:** There are two broad categorizations of microbial pathogens of interest. The first is zoonotic organisms and the second is opportunistic pathogens of environmental origin (e.g., soil). For simplification in this talk and abstract only the zoonotic microbes are discussed. Zoonotic organisms are defined as those disease and infections, which are naturally transmitted between vertebrate animals and man. For the purposes of this discussion on nonpoint source pollution, indirect transmission will be discussed (transmission via a vector such as water). The primary hosts for the organisms are an animal reservoir. The pathogen groups include viruses and prions, bacteria, fungi and protozoa.

**Viruses:** Some human enteric viruses can infect other animals, and animal reservoirs may be important. Reovirus type 3 can infect humans and other mammals including mice, and the interspecies transmission of rotavirus, including human infection by a bovine strain, has been reported. Hepatitis E viruses (HEV) of pigs and rats are very similar to human HEV. Human strains of HEV have experimentally infected pigs, and porcine strains have experimentally infected primates.

**Bacteria:** *E. coli* 0157:H7 is widely distributed in cows and other ruminants where it may not cause animal disease but can readily spread to humans through contaminated food and water. A wide range of domestic and wild animals including poultry, pigs, cattle, sheep, puppies, kittens, and rodents can serve as reservoirs for *Campylobacter jejuni*, an important cause of diarrhea throughout the world. Humans and a wide range of domestic and wild animals including poultry, cattle, birds, dogs, cats, rodents, and turtles can serve as reservoirs for *Salmonella*.

Animals are the principal reservoir for *Yersinia*, and humans and pigs are important reservoirs for *Y. enterocolitica*. Reservoirs for *Leptospira interrogans* include many wild and domestic animals including rats, dogs, raccoons, swine, and cattle. Contact of mucous membranes and the skin, especially if abraded, with contaminated water is one mode of transmission. Numerous wild animals, especially rabbits, muskrats, beavers, and some domestic animals can serve as reservoirs for *Francisella tularensis*.

**Protozoa:** *Cryptosporidium parvum* is likely infectious for all species of mammals; young animals are most prone to infection and illness. Many mammalian hosts can also carry *Giardia intestinalis*. Because humans are significant carriers of infection for both of these protozoa, the extent to which infections in animals contribute to human infection and illness is uncertain. Recent findings emphasize the need for more information about the species and genotype of *Cryptosporidium*; various isolates may be virulent to varying

degrees in humans. *Blastocystis hominis* has been found in monkeys, apes, pigs, dogs, cattle, sheep, and ducks. *B. hominis* has also been identified in stool specimens from ill persons in several waterborne outbreaks in the United States, but whether *B. hominis* was the cause of the reported illness is unclear because its pathogenicity is debated.

*Balantidium coli* is widely distributed in pigs in warm and temperate climates and in monkeys in the tropics. Human infection is generally found in warmer climates but can occur sporadically in cooler areas. *Toxoplasma gondii* infects virtually all warm-blooded hosts, but cats and other felines are the only definitive hosts. Intermediate hosts include rodents, sheep, pigs, cattle, and birds. Humans may be the only natural host of *Cyclospora cayetanensis*, but similar organisms have been observed in chimpanzees and baboons. *Microsporidia* produce a spore stage that survives in the environment. These protozoa are relatively ubiquitous in the environment and have been found in bird and mammal hosts including dogs and cats. Several species can infect humans. The disease and symptoms vary considerably.

**Pathways:** Excreted material and other animal waste products are the predominant sources of waterborne zoonotic pathogens. The key concentrated sources of the pathogens are: wastewater, feces; urine; and carcasses and abattoir waste. The principal vehicles of transmission of waterborne zoonotic pathogens are: drinking water; water contact (recreation); water used in food preparation, production and processing; and aerosolized material.

### **Data sources:**

**Disease Reporting:** Most of the above organisms are reportable diseases. The reporting of infectious diseases is voluntary at the federal level. The list of requested reporting organisms is revised and agreed upon by the Council of State and Territorial Epidemiologists. The data is reported to CDC's Notifiable Diseases Section for annual compilation. Many of the above organisms are unlikely to cause symptomatic illness in population and ill individuals rarely seek medical care for diarrhoea unless the illness becomes life threatening. Often those illnesses seen by a health care provider are rarely submitted to diagnostic testing.

### **Waterborne outbreaks caused by zoonotic agents**

A significant number of outbreaks and illnesses were caused by zoonotic agents (Table 1). Zoonotic agents can be found in human sewage as well as domestic and wild animal faeces. Because the source of the fecal contamination was either not investigated or not identified in many of the zoonotic outbreaks, it was not possible to evaluate the importance of animal versus human sources for the agents. Reported statistics should be evaluated with this limitation in mind.

Table 1. Waterborne Outbreaks Caused by Zoonotic Agents by Type of System, 1971-2000

Water System Type	Outbreaks of Zoonotic Agents	Percent of all Reported Outbreaks <sup>a</sup>	Percent of Outbreaks of Identified Etiology
Non-Community	46	14%	41%
Community	118	38%	56%
Untreated Recreational Water	43	30%	79%
Individual	25	24%	28%

<sup>a</sup> Includes outbreaks of unidentified etiology

Zoonotic agents caused 118 outbreaks in community systems. These outbreaks represent 38% of the 308 outbreaks reported in community systems or 56% of the 210 community system outbreaks where an etiology was identified. In outbreaks associated with untreated recreational waters, zoonotic agents caused 30% of the outbreaks or 79% of the outbreaks of identified etiology. Zoonotic agents were responsible for most of the illnesses (78%) and deaths (88%) that we reported in waterborne outbreaks. More than two-thirds of all emergency room visits and hospitalizations were reported in outbreaks caused by zoonotic agents. Fifty deaths and 4,400 hospitalizations were attributed to the Milwaukee cryptosporidiosis outbreak.

### Drinking water outbreaks

*Giardia*, *Campylobacter*, *Cryptosporidium*, *Salmonella*, and *E. coli* were the zoonotic agents most frequently identified in outbreaks caused by contaminated drinking water (Table 2). *Giardia* was identified in 66% of all drinking water zoonotic outbreaks and in 70%, 62%, and 56% of the zoonotic outbreaks in community, non-community, and individual systems, respectively. *Cryptosporidium* was identified in only 8% of the zoonotic outbreaks and in 9%, 4%, and 8% of the zoonotic outbreaks in community, non-community, and individual systems, respectively. *Campylobacter* was identified in 10% of the zoonotic outbreaks. Non-typhoid *Salmonella* caused 8% of the zoonotic outbreaks, and *E. coli* 0157:H7 caused 6% of the outbreaks.

Most (71%) outbreaks of giardiasis occurred in systems using surface water, whereas most (53%) outbreaks of cryptosporidiosis occurred in groundwater systems. Bacterial pathogens were identified in 49 (26%) of the zoonotic outbreaks and 20%, 34%, and 36% of the zoonotic outbreaks in community, non-community, and individual systems, respectively. Most (71%) outbreaks of zoonotic bacteria were reported in groundwater systems.

Table 2. Drinking Waterborne Outbreaks of Zoonotic Agents, 1971-2000

Etiologic Agent	Total	Type of Water System			Water Source		
		Community	Non-Community	Individual	Ground-water	Surface Water	Mixed or Unknown
<i>Giardia</i>	126	83	29	14	31	90	5
<i>Campylobacter</i>	19	9	7	3	12	3	4
<i>Cryptosporidium</i>	15	11	2	2	8	5	2
<i>Salmonella</i>	15	11	2	2	11	2	2
<i>E. coli</i> 0157:H7	11	4	4	3	8	2	1
<i>Yersinia</i>	2	-	1	1	2	-	-
<i>E. coli</i> 06:H16	1	-	1		1	-	-
<i>E. coli</i> 0157:H7 & <i>Campylobacter</i>	1	-	1		1	-	-
Total	190	118	47	25	74	102	14

Outbreaks caused by protozoan and bacterial zoonotic agents were evaluated to determine the water system deficiencies that were responsible for the outbreak. Inadequate disinfection as the only treatment of surface water and inadequate or interrupted treatment of surface water caused over half (52%) of the outbreaks of giardiasis and cryptosporidiosis. Eighteen percent of the outbreaks of giardiasis and cryptosporidiosis were due to contaminated, untreated or inadequately treated groundwater; 11% were associated with contamination entering the distribution system. Although untreated surface water was responsible for 10% of the outbreaks of giardiasis and cryptosporidiosis, almost all of these outbreaks occurred in the early 1970's before EPA regulations required treatment.

The three most important deficiencies identified for outbreaks of *Campylobacter*, *Salmonella*, *E. coli*, and *Yersinia* enteritis were: use of contaminated, untreated groundwater (29%), distribution system contamination (22%), and inadequate treatment of contaminated groundwater (20%). Few bacterial outbreaks were attributed to untreated or inadequately treated surface water.

### Outbreaks associated with untreated recreational water

Schistosomatidae caused 30% of the outbreaks of zoonotic etiology reported in untreated recreational waters (Table 3). *E. coli* and *Leptospira* each caused 30% and 16% of the outbreaks; *Giardia* or *Cryptosporidium* caused 23% of the outbreaks. Most (83%) outbreaks were associated with recreational activities in lakes or ponds.

Table 3. Outbreaks and Illnesses, Untreated Recreational Water, by Zoonotic Agent and Water Venue, 1971-2000

Etiologic Agent	Total Number Outbreaks	Lakes or Pond	River, Springs, and Other
Schistosomatidae	13	12	1
<i>E. coli</i> 0157:H7	12	11	1
<i>Leptospira</i>	7	4	3
<i>Giardia</i>	6	4	2
<i>Cryptosporidium</i>	4	4	-
<i>E. coli</i> 0121:H19	1	1	
Total	43	36	7

The source of contamination was identified in 24 recreational water outbreaks, (Table 4). Fecal contamination by bathers was identified in eleven of the *E. coli* outbreaks. An avian source was identified in seven outbreaks of schistosome dermatitis and suspected in six outbreaks. Animals including dogs, cattle, and water buffalo were suspected sources of *Leptospira* but could be identified in only one outbreak.

Table 4. Identified Causes of Outbreaks of Zoonotic Agents Associated with Untreated Recreational Water

Source of Contamination or Deficiency	<i>Cryptosporidium</i> & <i>Giardia</i>	Schistosomatidae	<i>E. coli</i>	<i>Leptospira</i>
Animals, Birds	2	7		1
Fecal Accident, Ill Bathers	1		5	
Children in Diapers	1		3	
Bather Overload or Crowding			3	
Seepage or Overflow of Sewage	1			

Total	5	7	11	1
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### Specific Studies

Very few studies have attempted to look at health effects associated with exposure to nonpoint source contaminated water. In the mid-1980s an epidemiologic study was conducted to evaluate the potential health risks to bathers that swam in water contaminated by organisms of other than point sources of pollution associated with human domestic wastewaters. The bacterial indicators used to measure the quality of water cannot distinguish water degradation caused by human fecal contamination from that caused by other sources. This study was designed to examine the relationship between water quality degraded by dispersed, unidentified sources of animal fecal contamination and health effects in swimmers.

There were no point sources of pollution, such as septic tanks, directly contaminating the study site. The local watershed was populated by many animals such as squirrels, rabbits, a few cows, deer and small rodents. As predicted the water quality indicators were correlated closely with precipitation events. The three fecal related indicator bacteria, fecal coliforms, *E. coli* and enterococci, were significantly correlated with each other. There was a significant association of total gastrointestinal illnesses, but not highly credible GI illnesses, associated with swimming. However, these swimming-associated illness rates were not correlated with any of the fecal indicators of water quality.

The University of California has recently reported on a marine recreational study of recreational water quality and swimmer illness. No point sources were identified in this study and as the previous study found no health effects were found associated with the bacterial indicators examined in the study.

### Needs and Gaps

There is a need for a risk-based approach to setting standards or guidelines of waterborne zoonotic illnesses. There is inadequate information on differentiation of human versus animal strains of human pathogens, both in the field and in the clinic. Efforts are needed to improve surveillance and diagnostics to make both Notifiable diseases reporting and outbreak investigations and reporting a more meaningful indication of the associated burden of disease and their risks.

Reference:

***Waterborne Zoonoses: Identification, Causes and Control.*** Edited by Cotruvo, Dufour, Rees, Bartram, Carr, Cliver, Craun, Fayer, and Gannon. WHO published 2004.